Complex Wavelet Based Demosaicing for use in Digital Still Cameras

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Abstract—**We present a new approach to the problem of demosaicing for digital still cameras (DSC) imagery. Most state-of-the-art methods come down to interpolating the missing color components pixelwise, resulting in quite complex implementations in order to avoid image artifacts [2, 3]. We propose solving the demosaicing problem in the wavelet domain, which turns out to be very elegant. By making this approach locally and directionally adaptive, using our new Dual Tree Complex Wavelet Packet (DTCWPT) decomposition, we can avoid demosaicing artifacts in a simpler way. This results in a very fast demosaicing approach that is extremely compatible with on-camera wavelet based denoising.**

I. Introduction

In a short timeframe, digital still cameras (DSC) have completely driven analog photography away from the consumer market. A digital image is discretized into picture elements (pixels), by focusing the image onto a grid of photosensitive cells. The more cells a camera has (i.e. the more Megapixels it has), the sharper the resulting image will be. However the modern consumer wants color images. Making a cell sensitive to multiple colors is difficult and as a result, more expensive. Making a cell sensitive to one color is very easy and cheap (e.g. through the use of color filters). We present a novel approach to the problem of demosaicing, which is the interpolation of a true color image from data acquired using a mosaic pattern of color filters (e.g. the one in figure 1).

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II. Demosaicing technique

A. Data model

Traditionally, the data is modelled as three subsampled color signals. We use a different model, we assume that we have one fully sampled green signal. On the positions where the green is not actually known, we assume to know the chrominance (i.e. the difference between red/blue and green) signals. This is illustrated on figure 1. As the Fourier transform

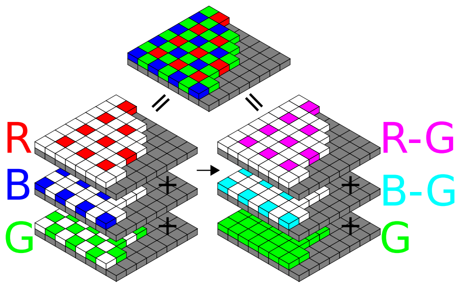


Figure 1. Color filter mosaic (top), interpreted as a sum of three subsampled color signals (left) or the sum of a fully sampled green signal and two subsampled chrominance signals (right)

is linear, the spectrum of the mosaic is a sum of the spectra of the three component signals from our model. Only the subsampled chrominance signals will cause alias copies at positions $\omega = \{-\pi, 0, \pi\}$. Assuming sufficiently low-pass behaviour from the component signals (figure 2), one can separate the different chrominance spectra from the green spectrum by using simple linear filters and making simple linear combinations of the outputs. This effectively constitutes demosaicing.

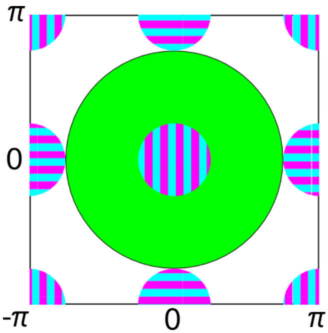


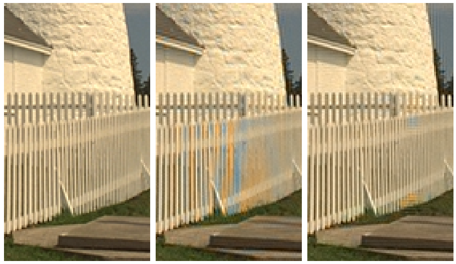
Figure 2. Spectrum of the mosaic, showing the low-pass assumptions on the different component signals, of which the contributions to the mosaic spectrum are color-coded

B. Complex Wavelet Transform

In [1], a similar method was proposed, which used the packet discrete wavelet transform (DWT) to implement the filtering in a local way. This way, errors in the aforementioned low-pass assumptions will only result in local artifacts instead of image-wide corruption. These artifacts occur in the vicinity of image features, edges corresponding to high frequencies. There are two types of artifacts: low frequency color corruptions, due to high green frequencies extending into the band of the alias copies of the chrominances, and high frequency zipper artifacts, due to the chrominance extending beyond its assumed bandwidth. Our proposed method uses a new transform, the DTCWPT in order to implement the local filtering. This transform has many advantages: it is less expansive than the undecimated packet DWT, which allows to perform wavelet demosaicing using 4 times less camera memory. The complex wavelets are nearly analytic and have excellent directionality, this allows to detect where (spatially) and why (the direction of the corrupting high frequencies) artifacts will occur with greater accuracy. The directionality then allows to isolate these high frequencies more precisely and exclude them locally in the reconstruction process, resulting in artifact-free demosaicing. By exploiting the presence of multiple alias copies of the chrominance spectra in different parts of the mosaic spectrum (figure 2), our locally adaptive reconstruction even makes it possible to reconstruct the corrupting high green frequencies responsible for some of the artifacts.

III. Results

In figure 3, present some results from an experiment with the *lighthouse* image.



(a) (b) (c)

Figure 3. Demosaicing results: (a) original image (b) wavelet-based demosaicing from Hirakawa et al. (c) proposed method

We see that the proposed method eliminates most artifacts and does a better job at reconstructing high frequencies.

IV. Conclusion

The proposed approach contrasts greatly with existing state-of-the-art demosaicing techniques because it is wavelet-based, but achieves great visual quality and is much faster than existing techniques. An added advantage is that it can be integrated with on-camera wavelet-based denoising, increasing the combined processing speed as only one wavelet transform is needed for both operations.

References

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[2] Lei Zhang and al., *Color Demosaicking via Directional Linear Minimum Mean Square-Error Estimation* IEEE Trans. on Image Processing, vol.14, no.12, Dec. 2005

[3] Bahadir K. Gunturk and al., *Color Plane Interpolation using Alternating Projections* IEEE Trans. on Image Processing, vol.11, no.9, Sept. 2002